cells. To discover that DNA was the hereditary material and determine the mechanism by which it replicated, new tools had to be developed. This was done by molecular biologists in the 1940s and 1950s, but from the point of view of cell mechanisms, those discoveries filled in the schema developed much earlier (Darden, 2005). I will briefly analyze this case in Chapter 3, but otherwise my focus will be on mechanisms situated in the cytoplasm of the cell, that is, all of the cellular materials enclosed within the cell membrane excepting the nucleus.

The cytoplasm is the locus of a host of cellular mechanisms that are responsible for taking in material from the cell's environment, breaking down this material as well as worn out pieces of its own structure, and synthesizing new components of its own structure or materials for export out of the cell. All of these mechanisms require energy; accordingly, several additional mechanisms are devoted to procuring and making energy available to them. To understand any of these mechanisms, it was not enough to have ideas about the phenomena they produced; scientists needed means of investigation. With the development of stains in the late nineteenth century, cytologists began to secure evidence of the occurrence of structures, called *organelles*, in what until then had appeared as formless cytoplasm. However, the evidence was highly contested and would be until techniques became available that went beyond those of light microscopy. Biochemists, on the other hand, routinely destroyed cell structure because it provided the best means of securing preparations in which they could study chemical reactions. To link reactions to the particular organelle in which they occurred (and in some cases to study them at all) required more refined preparations. Two instruments developed by physicists and chemists in the 1920s and 1930s offered promise for entering these unexplored territories – the electron microscope and the ultracentrifuge. Biologists, however, confronted significant challenges in developing the techniques needed to deploy these instruments to study mechanisms operative in cells. These challenges and the techniques that were created to surmount them will be examined in Chapter 4.

New research techniques pose both an engineering and an epistemic challenge. As in prototypical engineering tasks, in order to use the ultracentrifuge or the electron microscope, researchers had to figure out ways to accomplish new tasks – for example, to release the contents of cells from the cell membrane without disrupting internal structures and to stain cell components so that they would differentially diffract electrons. Engineering tasks like these give rise to the epistemic challenge of showing that the results reflect the phenomenon of interest and are not artifactual. Because the evaluation of engineering solutions is frequently grounded in empirical exploration, rather